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Certificate of Forward Translation

The undersigned, Kang, KB, hereby declares to have supplied a true and accurate forward translation with the name, "KR Priority Document" into English from the Korea document with the name, "KR Priority Document_EN_FN".

I certify that I am a professional translator in the following language pair: Korean>English and English>Korean, with translation experience in the patent over 11 years.

Signed: Kang, KB

[Amendment]

[Item to be amended] Identification number 18
[Method of Amendment] Corrected
[Amendment contents]

Being different from existing glass and plastic lens which have to include separate driving devices described above, a lens suggested in US Patent No. 702785 entitled "Variable geometry liquid-filled lens and method for controlling the energy distribution of light beam" has a lens material of liquid state, so it has a property that curvature of its surface changes depending on amplitude of biased voltage and waveform of the signal. Further, using such a property, it is possible to realize high-level functions such as auto focusing, auto zooming and auto macro with a lens even in a narrow space of a movable information terminal.

[Item to be amended] Claim 1
[Method of Amendment] Correction
[Contents of Amendment]
[Claim 1]

A Liquid lens driver circuit for receiving a lens driver control signal (CTL) from an image signal processor (ISP) and driving a liquid lens, comprising: an input/output interface for exchanging the lens driver control signal and a state information data of the liquid lens with an image signal processor according to a desired signal transmission protocol; a system clock generator for generating a system clock; a high voltage generator (hv) for generating a high voltage to drive the liquid lens from a low voltage of a battery in a mobile information terminal; a reference/bias voltage generator for providing a reference voltage and a bias voltage to operate the liquid lens driver circuit; a driver signal generator for generating an output waveform to drive the liquid lens and then generating the final driving signal of the liquid lens

by increasing the output waveform to a high voltage level generated in the high voltage generator; and a controller for controlling each functional unit to drive the liquid lens.

[Item to be amended] Claim 11
[Method of Amendment] Correction
[Contents of Amendment]
[Claim 11]

The liquid lens driver circuit according to claim 10, wherein the high voltage generator further comprises a voltage distribution module for dividing the high voltage (hv) converted in the said converter module in a desired ratio and generating a divisional voltage (div_hv) which is lower than the said high voltage; and a voltage comparison module for comparing the curvature reference voltage (Vref) needed to drive the liquid lens and the , and divisional voltage providing the voltage conversion control module with a control signal (ovv) when the divisional voltage exceeds the curvature Vref.

[Item to be amended] Claim 12
[Method of Amendment] Correction
[Contents of Amendment]
[Claim 12]

The liquid lens driver circuit according to claim 1, wherein the reference/bias voltage generator comprises a reference/bias voltage provision module for providing electronic devices in the liquid lens driver circuit with the bias voltage and reference voltage; and a curvature reference generation module for generating an analog voltage corresponding to the drive voltage of the liquid lens transmitted from the image signal processor and providing the voltage comparison module with the curvature reference voltage (Vref).

[Item to be amended] Claim 15

[Method of Amendment] Correction
[Contents of Amendment]
[Claim 15]

A high voltage generator for generating a high voltage used to drive a liquid lens, comprising: a converter module for converting a battery voltage of a mobile information terminal into a high voltage to drive the liquid lens; a voltage conversion clock generation module for generating a voltage conversion clock (dc_clk) used when converting a direct voltage in the converter; a voltage conversion control module (R-S Latch module) for stopping operation of the converter module to stop the voltage conversion when the high voltage (hv) generated in the converter module exceeds the voltage to drive the liquid lens (reference voltage) so as to make a voltage conversion; a voltage division module for dividing a high voltage converted in the converter module in a desired ratio and generating a divisional voltage (div_hv) which is lower than the high voltage; and a voltage comparison module for comparing a curvature reference voltage (Vref) needed to drive the liquid lens and a divisional voltage (div_hv) generated in the voltage division module, and providing the voltage conversion control module with a control signal (ovv) when the divisional voltage (div_hv) exceeds the curvature reference voltage (Vref), wherein the voltage conversion clock generation module generates a plurality of clocks which have different frequencies to selectively use voltage conversion clocks needed in the converter module, wherein the converter module for selecting and using the plurality of clocks generated in the voltage conversion clock in variableness according to properties of constitutional electric devices (inductor, capacitor, diode) of the converter module.

[Item to be amended] Claim 19
[Method of Amendment] Correction
[Contents of Amendment]

[Claim 19]

The high voltage generation circuit according to claim 17, wherein the transient current detection voltage comparator performs comparison only when the first and second transistors are driven after receiving the control signal.

[Item to be amended] Claim 20
[Method of Amendment] Deletion
[Item to be amended] Claim 21
[Method of Amendment] Deletion

[Patent Claims]

[Claim 1]

A Liquid lens driver circuit for receiving a lens driver control signal (CTL) from an image signal processor (ISP) and driving a liquid lens, comprising: an input/output interface for exchanging the lens driver control signal and the state information data of the liquid lens with an image signal processor according to a desired signal transmission protocol; a system clock generator for generating a system clock; a high voltage (hv) generator for generating an high voltage to drive the liquid lens from a low-voltage battery in a mobile information terminal; a reference/bias voltage generator for providing a reference voltage (Vref) and a bias voltage to operate the liquid lens driver circuit; a driver signal generator for generating a desired output waveform to drive the liquid lens and then generating the final driving signal of the liquid lens by increasing the output waveform to a high voltage level generated in the high voltage generator; and a controller for controlling each functional unit to drive the liquid lens.

[Claim 2]

The liquid lens driver circuit according to claim 1, wherein the liquid lens driver circuit is included in each liquid lens, and each liquid lens driver circuit has its own ID.

[Claim 3]

The liquid lens driver circuit according to claim 1, wherein when the lens driver control signal and the state information data of the liquid lens exchanged in the input/output interface, a 2-wire serial communication scheme is used, including a clock signal wire used to exchange a control clock signal for controlling the image information exchange control, and a data signal wire used to exchange data related to the image information and determine the power source state of the liquid lens driver

circuit.

[Claim 4]

The liquid lens driver circuit according to claim 1, wherein when the lens driver control signal and the state information data of the liquid lens are exchanged in the input/output interface, a 3-wire serial communication scheme is used, including a clock signal wire used to exchange a control clock signal to control the image information exchange control, a data signal wire used to exchange data related to the image information, and a power source control wire used to determine the power source operation state of the liquid lens driver circuit.

[Claim 5]

The liquid lens driver circuit according to claim 3 or 4, wherein the determination of the power source operation state of the liquid lens driver circuit disables all the reference voltage and bias voltage in the liquid lens driver circuit and turns off the system clock generator to stop the operation of the liquid lens driver circuit when a power source off mode signal is applied.

[Claim 6]

The liquid lens driver circuit according to claim 3 or 4, wherein the determination of the power source operation state of the liquid lens driver circuit enables all the Vrefs and bias voltage in the liquid lens driver circuit, and turns on the system clock generator to operate the liquid lens driver circuit normally when a power source normal mode signal is applied.

[Claim 7]

The liquid lens driver circuit according to claim 1, wherein when the lens driver control signal and the state information data of the liquid lens are exchanged in the input/output interface, and an efficient data signal is received from the data signal wire by synchronizing the signal and data with the clock signal transmitted from the clock signal wire.

[Claim 8]

The liquid lens driver circuit according to claim 1, wherein when the lens driver control signal and the state information data of the liquid lens are exchanged in the input/output interface, the information exchange is performed by setting a register value in the input/output interface and reading/writing the register.

[Claim 9]

The liquid lens driver circuit according to claim 1, wherein when the lens driver control signal and the state information data of the liquid lens are exchanged in the input/output interface, the information exchange is performed by each controlling the respective liquid lens driver circuit selectively, using the unique ID of each liquid lens driver circuit.

[Claim 10]

The liquid lens driver circuit according to claim 1, wherein the high voltage generator comprises a converter module for direct-voltage converting the battery voltage of the mobile information terminal into a high voltage to drive the liquid lens;

a voltage conversion clock generation module for generating a voltage conversion clock (dc_clk) used when performing the direct voltage conversion in the converter module; and

a voltage conversion control module (R-S Latch module) for stopping the operation of the converter module and then stopping the voltage conversion when the high voltage generated in the converter module exceeds the voltage (reference voltage) needed to drive the liquid lens and the voltage conversion is made.

[Claim 11]

The liquid lens driver circuit according to claim 10, wherein the high voltage generator further comprises a voltage distribution module for dividing the high voltage converted in the converter module into a desired ratio and generating a desired divisional voltage (div_hv) which is lower than the high voltage; and

a voltage comparison module for comparing the curvature reference voltage (Vref) needed to drive the liquid lens and the divisional voltage (div_hv), and providing the voltage conversion control module with a control signal (ovv) when the divisional voltage (div_hv) exceeds the curvature reference voltage (Vref).

[Claim 12]

The liquid lens driver circuit according to claim 1, wherein the reference/bias voltage generator comprises a reference/bias voltage provision module for providing electronic devices in the liquid lens driver circuit with the bias voltage and a desired reference voltage; and

a curvature reference generation module for generating an analog voltage corresponding to the drive voltage of the liquid lens transmitted from the image signal processor, and providing the voltage comparison module with the curvature reference voltage (Vref).

[Claim 13]

The liquid lens driver circuit according to claim 1, wherein the drive signal generator comprises a drive signal clock generation module for generating the drive clock (fd) in a waveform period of a signal which drives the liquid lens;

a low voltage differential signal generation module for generating two low voltage differential signals (fdrv) from the drive clock, the low voltage differential signal having differential type and battery voltage level of the mobile terminal; and

a high voltage (hv) differential signal generation module for generating a plus drive signal (DRVP) and a minus drive signal (DRVM) which are liquid lens final drive signals of differential type, by increasing the voltage amplitude of the low voltage differential signal (fdrv) to a high voltage level in the high voltage generator.

[Claim 14]

The liquid lens driver circuit according to claim 1, wherein the input/output interface, the system clock

generator, the high voltage generator, the reference/bias voltage generator, the drive signal generator, and the controller are embedded and integrated into a single chip.

[Claim 15]

A high voltage generator for generating a high voltage used to drive a liquid lens, comprising:

a converter module for converting the battery voltage of a mobile information terminal into a high voltage to drive the liquid lens;

a voltage conversion clock generation module for generating a voltage conversion clock (dc_clk) used when converting direct voltage in the converter;

a voltage conversion control module (R-S Latch module) for stopping the operation of the converter module to stop the voltage conversion when the high voltage generated in the converter module exceeds the voltage required to drive the liquid lens (reference voltage) so as to perform a voltage conversion;

a voltage division module for dividing a high voltage (hv) that has been converted in the converter module into a desired ratio, and generating a desired divisional voltage (div_hv) which is lower than the high voltage; and

a voltage comparison module for comparing a curvature reference voltage (Vref) needed to drive the liquid lens and a divisional voltage (div_hv) generated in the voltage division module, and providing the voltage conversion control module with a control signal (ovv) when the divisional voltage (div_hv) exceeds the curvature reference voltage (Vref).

[Claim 16]

The high voltage generation circuit according to claim 15, wherein the converter module comprises a DC-DC converter stage embodied in a discontinuous current mode, in which current flowing in an inductor (L) is not flowed continuously;

a transient current detection stage for detecting transient current flowing in the said inductor (L) and a

first transistor to perform voltage amplification conversion and generate a transient current detection signal (ovc); and

a logical AND gate for performing a logical AND of a transient current detection signal (ovc) transferred from the transient current detection stage and a voltage conversion clock generated in the current conversion clock generation module, and generating a first transistor drive clock (drv_clk) being a bias voltage signal in the first transistor.

[Claim 17]

The high voltage generation circuit according to claim 16, wherein the transient current detection stage comprises a second transistor whose capacity is 1/N of the first transistor (N is an integer);

a constant current source for calculating an available maximum current (Imax) flowing through the inductor (L) and the first transistor in the DC-DC converter and flowing a constant current (Iref), whose value is obtained by dividing the maximum current (Imax) by the integer N (that is, the maximum current/N); and

a transient current detection voltage comparator for comparing an amplification voltage (V1) obtained when the first transistor in the DC-DC converter stage is operated and an amplification voltage (V2) of the second transistor is obtained when the constant current (Iref) is generated in the constant current source, and generating the transient current detection signal (ovc) in the case that the voltage (V1) is higher than the voltage (V2).

[Claim 18]

The high voltage generation circuit according to claim 17, wherein the constant current source receives a transient current detection control signal (dc_cnt) that controls the current volume variously in the controller and flows a constant current (Iref) corresponding to the consuming current and driving voltage of the liquid lens.

[Claim 19]

The high voltage generation circuit according to claim 17, wherein the transient current detection voltage comparator performs comparison only when the first and second transistors are driven after receiving a desired control signal.

[Claim 20]

The high voltage generation circuit according to claim 15, wherein the voltage conversion clock generation module generates a plurality of clocks of various frequencies, so as to selectively use the voltage conversion clocks needed in the converter module.

[Claim 21]

The high voltage generation circuit according to claim 15, wherein the converter module variably selects and uses the plurality of clocks generated in the voltage conversion clocks according to the properties of the constructional devices (inductor, capacitor and diode) of the converter module.

[Claim 22]

A drive signal generation circuit for generating an output waveform to drive a liquid lens, comprising:

a drive signal clock generation module for generating a drive clock (fd) in a waveform period of a signal to drive the liquid lens;

a low-voltage differential signal generation module for generating two low-voltage differential signals (fdrv) from the drive clock, the low-voltage differential signal having a differential type and battery voltage level than the mobile terminal; and

a high voltage differential signal generation module for generating a plus drive signal (DRVP) and a minus drive signal (DRVM) which are liquid lens final drive signals of differential type, by increasing the voltage amplitude of the low voltage differential signal (fdrv) to a high voltage (hv) level in the high voltage generator.

[Claim 23]

The drive signal generation circuit according to

claim 22, wherein the drive signal clock generation module generates a plurality of clocks having various frequencies, so as to selectively use the optimum differential signal period with which the low-voltage differential signal generation module drives the liquid lens.

[Claim 24]

The drive signal generation circuit according to claim 22, wherein the liquid lens is driven in the form of the differential signal by connecting either a plus drive signal (DRVP) or a minus drive signal (DRVM) generated in the high voltage differential signal generation module to one terminal of the liquid lens, and the other signal to the other terminal.

[Claim 25]

The drive signal generation circuit according to claim 22, wherein the high voltage differential signal generation module comprises a voltage level converter for converting the voltage level of the low-voltage drive signal (fdrv) generated in the low-voltage differential signal generation module into a high voltage (hv) level input from the converter module and generating the plus drive signal (DRVP) and the minus drive signal (DRVM), which are liquid lens final drive signals;

first and second buffers for buffering the plus drive signal (DRVP) and the minus drive signal (DRVM) generated in the voltage level converter in the liquid lens; and

a slope control resistor for allowing the rising and falling times (Tr) and (Tf) of the plus drive signal (DRVP) and the minus drive signal (DRVM) to have predetermined slopes, regardless of the signal amplitudes thereof.

[Description]

[Title of the invention]

Driver of liquid-filled lens generating high-voltage drive signal

[Brief description of the drawings]

Fig. 1a is an interior constructional view of a liquid-filled lens.

Fig. 1b is a graphical view showing a curvature slope according to the voltage applied to the liquid-filled lens.

Fig. 2 is a view showing a differential signal driving the liquid-filled lens according to the present invention.

Fig. 3 is a block diagram showing a driving feature of the liquid-filled lens.

Fig. 4 is an interior constructional block diagram of the liquid-filled lens according to the present invention.

Fig. 5 is a view showing voltage conversion clocks generated in a voltage conversion clock generation module.

Fig. 6 is a view showing an interior construction of a DC-DC converter stage.

Fig. 7 is a view showing an interior construction of a transient current detection stage.

Fig. 8 is a timing diagram of each signal in the liquid-filled lens driver circuit.

Fig. 9 is a view showing an interior construction of a high voltage differential signal generation module.

[Detailed description of the invention]

[Object of the invention]

[Technical field and prior art]

The present invention relates to a liquid-filled lens driver circuit for generating a liquid-filled lens drive signal and its integrated circuit, capable of generating an high voltage drive signal from a low-voltage source, and then a differential-type drive signal, so as to enhance RMS voltage between two electrodes of the liquid-filled lens

applied by the high voltage drive signal to drive the liquid-filled lens.

Current digital camera functions are necessarily applied not only to the digital camera set itself but also to mobile phones, mobile information terminals and the like. However, such mobile information terminals can only embody the basic functions of the digital camera because of their small sizes, and have many difficulties in embodying high-level functions such as autofocus, auto-zoom, auto-macro and the like because their lenses and mechanical lens drive devices are so small.

That is, in order to embody such high level functions, rather than the basic lens the camera should be equipped with a set of lenses, comprising for example a close-up lens, a standard lens and a telephoto lens, and these lens should be used interchangeably according to the photo subject. Furthermore, in order to embody the autofocus function, a drive device such as an electric motor or a piezo device which can change the optical property (focal distance) of a lens and control the change in the optical property should be equipped separately. As such, it is difficult for a small size mobile information terminal to embody a lens having such high-level functions.

Different from existing glass and plastic lenses with separate drive devices, a lens suggested in US Patent No.70278596 entitled "Variable geometry liquid-filled lens and method for controlling the energy distribution of light beam" consists of a liquid-state material as its lens substance, wherein the curvature of its surface is changed according to the amplitude of biased voltage and the waveform of the applied signal. Using such properties, it is possible to embody high-level functions such as autofocus, auto-zoom and auto-macro in a single lens, even in the narrow space available in the mobile information terminal.

That is, such a liquid-filled lens is an optical lens that can be used in a mobile phone or PDA with a camera

function, and in a general digital camera, which is different from the general lens in that its material is not glass or plastic but a special material that is liquid in state. In particular, the refraction indexes of light passing through the lens are changed by the voltage applied to the lens, which is composed of two liquid surfaces with different properties.

Using the properties of such liquid-filled lens, it is possible to embody the focusing and zooming functions using circuits to control voltage, which is different from the mechanics used to embody the focusing and zooming functions in existing lens sets. Therefore, it is possible to embody such functions in a camera whose size and cost are lower than those that use existing lenses, and thus user convenience is enhanced.

However, in order to drive such a liquid-filled lens, a drive voltage higher than that of the typical battery (electric cell) used in a mobile information terminal is needed. Furthermore, the lens should be driven with signals that suit the electric and optical properties of the liquid-filled lens.

That is, while voltage of a specific form should be applied to two terminals of the liquid-filled lens in order to efficiently drive the liquid-filled lens, it is difficult to embody a drive circuit that generates high voltage to drive the liquid-filled lens in a very narrow space, considering the construction of application devices (mobile phone, PDA, digital camera) in which such a liquid-filled lens is mounted.

[Technical object of the invention]

It is an object of the invention to suggest a liquid-filled lens driver circuit that includes a voltage conversion circuit, a drive signal generation circuit, a high voltage driver circuit, and an external interface related circuit, which are devised to construct an optimized circuit to drive the liquid-filled lens described

above, and a chip in which the liquid-filled lenses are integrated. Furthermore, it is another object of the invention to guarantee the stability of the driver circuit by detecting over-current and over-voltage and controlling them.

[Construction of the invention]

According to an aspect of the invention, there is provided a liquid lens driver circuit for receiving a lens driver control signal from an image signal processor and driving a liquid lens, including: an input/output interface for exchanging the lens driver control signal and state information data of the liquid lens with an image signal processor according to a desired signal transmission protocol; a system clock generator for generating a system clock; a high voltage generator for generating a high voltage to drive the liquid lens from the low voltage of a battery in a mobile information terminal; a reference/bias voltage generator for providing a reference voltage and a bias voltage to operate the liquid lens driver circuit; a driver signal generator for generating a desired output waveform to drive the liquid lens and then generating the final driving signal of the liquid lens by increasing the output waveform to a high voltage level generated in the high voltage generator; and a controller for controlling each functional unit to drive the liquid lens.

According to another aspect of the invention, there is provided a high voltage generator for generating a high voltage used to drive a liquid lens, including: a converter module for converting battery voltage of a mobile information terminal into a high voltage to drive the liquid lens; a voltage conversion clock generation module for generating a voltage conversion clock used when converting direct voltage in the converter; a voltage conversion control module (R-S Latch module) for stopping the operation of the converter module to stop the voltage conversion when the high voltage generated in the converter

module exceeds the voltage required to drive the liquid lens (reference voltage) so as to make a voltage conversion; a voltage division module for dividing a high voltage (hv) converted in the converter module in a desired ratio and generating a desired divisional voltage (div_hv) which is lower than the high voltage; and a voltage comparison module for comparing the curvature reference voltage (Vref) needed to drive the liquid lens and the divisional voltage (div_hv) generated in the voltage division module, and providing the voltage conversion control module with a control signal when the divisional voltage (div_hv) exceeds the curvature reference voltage (Vref).

According to yet another aspect of the invention, there is provided a drive signal generation circuit for generating an output waveform to drive a liquid lens, including: a drive signal clock generation module for generating a drive clock (fd) in a waveform period of a signal to drive the liquid lens; a low-voltage differential signal generation module for generating two low-voltage differential signals (fdrv) from the drive clock, the low-voltage differential signals (fdrv) having differential type and battery voltage level of the mobile terminal; and a high voltage (hv) differential signal generation module for generating a plus drive signal (DRVP) and a minus drive signal (DRVM) which are liquid lens final drive signals of differential type, by increasing the voltage amplitude of the low voltage differential signal to a high voltage level in the high voltage generator.

Hereinafter, the most preferred embodiment of the invention will be described with reference to drawings.

Fig. 1a is a view showing a construction wherein a drive voltage is applied to a liquid-filled lens, and Fig. 1b is a view showing a lens refraction index according to the voltage applied to the liquid-filled lens.

In the liquid-filled lens, as shown in Fig. 1a, when

an insulator (102) is mounted on a bottom electrode (104), a special liquid material (106) is mounted thereon, and then an electrode is connected so as to apply voltage to the liquid-filled lens, and the liquid-filled lens is refracted according to the voltage applied so the light passing through it is refracted. One of the two terminals of the liquid-filled lens is grounded (GND) and the other is connected to the electrode, so that the curvature of the liquid-filled lens can be changed.

The refraction of light passing through the lens corresponds to the voltage changes according to the voltage as shown in Fig. 1b (US Patent No.70278596). Accordingly, a desired volume of change in focal distance can be obtained by changing the refraction index of a desired lens using an appropriate voltage obtained in the relation between the voltage and the refraction index.

However, the voltage to drive the liquid-filled lens should be higher than that of the battery used in the mobile information terminal, which is mainly used in this invention. Therefore, in order for the liquid-filled lens to be driven using the low voltage generated in the battery of the mobile information terminal, the invention converts the voltage from the battery voltage of the mobile information terminal into a relatively high voltage, and drives the liquid-filled lens by making the drive signal of the liquid-filled lens in a differential form, as shown in Fig. 2.

The voltage conversion is performed in a high voltage generator (420), which is described in detail with reference to Fig. 4.

The drive signal shown in Fig. 2 in a differential form is generated in the drive signal generator (460) shown in Fig. 4, and can increase the RMS voltage applied between two electrodes of the liquid-filled lens by making the drive signal in the differential form.

While one of the two terminals of the lens is grounded (GND) and the other is connected to the electrode

in the art, the lens of the invention is driven by connecting one of the two terminals of the lens to a minus drive signal (DRVM; 20)4 and the other to a plus drive signal (DRVP 202), so that a relatively high (RMS voltage) can be obtained.

That is, since a higher RMS voltage can be obtained compared to using a differential signal by applying the minus drive signal (204) to one electrode of the two terminals of the lens and the plus drive signal (202) to the other electrode, it is possible to output a high voltage drive signal sufficient to drive the liquid-filled lens with the low voltage of the mobile information terminal.

Meanwhile, rising time (Tr; 212) and falling time (Tf; 214) from 10% to 90% of the differential signal are selected according to the property of the liquid-filled lens to be used, and a period (T; 206) and a half period (T1, T2; 208, 210 are determined by the properties of the lens. Accordingly, the waveform of the differential signal should be designed to have desired slopes (Tr, Tf), in consideration of the response properties of the refraction index with respect to EMI noise occurring by the voltage of the signal to drive the liquid-filled lens and the voltage change rate of the liquid-filled lens.

Fig. 3 is a block diagram showing a connection between a lens set, an image sensor, an image signal processor and a liquid-filled lens driver of the invention.

The image signal processor (300) generates a lens driver control signal (CTL) to drive the liquid-filled lens using properties of the image input from the lens set (320) through the image sensor (340).

The lens set (320) is comprised of existing optical lenses and the liquid-filled lens. It is used as a lens set comprised of normal optical lenses and a liquid-filled lens when supporting an autofocus function or an auto-macro function, and as a lens set comprised of existing optical lenses and two or more liquid-filled lenses when supporting

an auto-zoom function.

If there are a number of liquid-filled lenses in the lens set, there exists for each a liquid-filled lens driver circuit (400) to control those liquid-filled lenses, and the liquid-filled lens driver circuits (400) have unique IDs assigned thereto, respectively, so that the image processor can select the liquid-filled lens driver circuit to be controlled among the liquid-filled lens driver circuits to transmit the lens driver control signal.

Consequently, the liquid-filled lens driver circuit (400) of the invention is a driver circuit that drives a number of liquid-filled lenses in the lens set (320), which receives the lens driver control signal (CTL) input from the image signal processor and generates a differential signal of a signal (DRV) to drive the liquid-filled lens so as to output it as shown in Fig. 2.

While the liquid-filled lens driver circuit (400) is shown as a block in Fig. 3, it is clear that when there exist a number of liquid-filled lenses in the lens set, there may exist a number of driver circuits assigned to the liquid-filled lenses, respectively.

Fig. 4 is an interior constructional block diagram of the liquid-filled lens driver circuit shown in Fig. 3.

The liquid-filled lens driver circuit is generally comprised of an input/output interface (402), a controller (404), a system clock generator (406), a high voltage generator (420), a reference/bias voltage generator (440), and a drive signal generator (460).

The input/output interface (402) employs a serial/parallel communication scheme or another undetermined signal transmission scheme, which transmits and receives signals to or from (ISP; 300). It decodes the lens driver control signal (CTL) received from the image signal processor (300) and transmits the state of the liquid-filled lens to the image signal processor according to a desired signal transmission rule. Furthermore, the

input/output interface (402) receives a curvature of the liquid-filled lens and state information on whether the power operates normally from the controller (404) and transmits them to (ISP;300).

In order to perform the tasks described above, the input/output interface is comprised of two or three lines (401) to interface with the image signal processor.

In the case of a 2-wire serial communication scheme, one signal wire is a clock signal wire related to a clock and the other is a data signal wire related to the liquid-filled lens data. At this time, the data signal wire serves to take the interface of a power control signal to control a power source other than the liquid-filled lens related data.

Then, a separate power control wire is added to the clock signal wire and data signal wire to control the power of the liquid-filled lens driver circuit, so that the lens driver control signal (CTL) can be comprised of 3 wires (3-wire serial communication scheme).

When the lens driver control signal is comprised of 3 wires, one of them is a clock-related signal wire, another is a data-related signal wire, and the remaining one is a power control signal wire used to determine power down mode or normal operation mode.

The clock signal wire and data signal wire serve to receive instructions to make types of controls and data to control the curvature of the lens, or to perform the function to transmit the interior state. That is, the input/output interface sets values of the register by writing or reading desired data to or from the address of the interior register, and the image signal processor (ISP) sets the values of the register as described above, thereby controlling the liquid-filled lens driver circuit and setting the voltage value to drive the liquid-filled lens.

The liquid-filled lens driver circuit selects power down mode or normal operation mode according to the state of the power control signal wire. When the liquid-filled

lens driver circuit receives a power down mode message from the power control signal wire, it disables all bias voltages of the liquid-filled lens driver lens so as to minimize the power consumption of the liquid-filled lens driver circuit, and stops the operation of the high voltage generator and drive signal generator by stopping the interior clock generator.

If when embodying an object auto-zoom function, it is required to mount a number of the liquid-filled lenses on the mobile information terminal to drive them case by case, the liquid-filled lenses have to include liquid-filled lens driver circuits to drive each of them, respectively.

Accordingly, in order to enable the image signal processor (300) to discriminate between the liquid-filled lens driver circuits and transmit the control signal and data signal, the liquid-filled lens driver circuits are each assigned unique IDs. Accordingly, the image signal processor can selectively use the liquid-filled lens driver circuit by transmitting each unique ID of the liquid-filled lens altogether when transmitting the control signal to a specific liquid-filled lens driver circuit using the clock signal wire and the data signal wire.

While the input/output interface exchanges the lens driver control signal and the like with image signal processor (ISP; 300) as described above, it does not necessarily receive the lens driver control signal or the like from the image signal processor (ISP) in embodying the invention. That is, it is possible to equip a separate liquid-filled lens driver control signal generator to provide the liquid-filled lens driver control signal and the like, instead of the image signal processor (ISP). Accordingly, the image signal processor in the following detailed description and claims should be understood as including the liquid-filled lens driver control signal generator to provide a control signal so as to drive the liquid-filled lens driver as well as the existing image signal processor.

The controller (404) generates signals to control the high voltage signal generator (420), the reference/bias voltage generator (440), and the drive signal generator (462) using the signal received from the input/output interface.

The system clock generator (406) is an oscillator for generating precise frequencies, which is an R-C type oscillator that can be easily mounted in a semiconductor chip, since the crystal oscillator cannot be used outside the system of the invention due to space limitations.

The high voltage generator (420) generates high voltage, which is comprised of a voltage conversion clock generation module, a voltage conversion control module, a converter module, a voltage distribution module, and a voltage comparison module. It serves to generate the high voltage needed to drive the liquid-filled lens from the battery voltage of the mobile information terminal.

While the battery voltage of the mobile information terminal generally provides voltage lower than 5V, the voltage needed to drive the liquid-filled lens is in the range of 40V to 60V. Accordingly, the high voltage generator (420) generates the high voltage needed to drive the liquid-filled lens from the low voltage of the mobile information terminal.

The converter module (426) is a converter to convert a low direct voltage into a high direct voltage (DC to DC converter), which operates as a direct boost-up DC to DC converter to increase the voltage from the low voltage of the battery to a high voltage to drive the liquid-filled lens.

The converter module (426) is generally comprised of a DC-DC converter stage (610), a transient current detector stage (601) and a logical AND gate (602) as shown in Fig. 6, and a detailed description of these will be given with reference to Fig. 6. Here, there is described a property of the DC-DC converter stage (610) which is a core of the converter module (426).

Since the current consumed to drive the liquid-filled lens is comparatively small, and is used to charge or discharge a capacitor component of the lens (several hundreds of pF, generally), the DC-DC converter stage (610) is constructed in a discontinuous current mode DC to DC converter fashion.

Different from a general continuous current mode DC to DC converter fashion in which the current flowing in an inductor (604) shown in Fig. 6, the discontinuous current mode DC to DC converter fashion has a short time when the current of the inductor is zero at a DC to DC conversion time. The discontinuous current mode DC to DC converter will not be described in detail since it is well known in the art.

Generally, the discontinuous current mode DC to DC converter used in the invention is not used in a DC converter of boost-up fashion (a fashion where a high voltage is generated from a low voltage) but a DC converter of buck fashion (a fashion where a low voltage is generated from a high voltage).

However, the reason why the discontinuous current mode DC to DC converter is used to embody the invention is that the voltage to be increased from the battery voltage of the mobile information terminal is much higher than the battery voltage, the power consumed in the liquid-filled lens is very low, and a DC conversion clock of higher frequency should be used to employ a small volume of inductor since application products of the invention are used in small products such as mobile phones, digital camera and the like.

The voltage conversion clock generation module (422) is a circuit to generate a voltage conversion clock (dc_clk) used in the converter module (426). Fig. 5 shows voltage conversion clocks generated in the voltage conversion clock generation module. The reason why the clocks generated in the voltage conversion clock generation

module are different one another as shown in Fig. 5 is that clocks needed in the DC to DC converter are selected from the generated clocks and used.

That is, while values of inductor (L), capacitor (C) and diode (D) are tuned after finishing a design of the converter when constructing a general DC-DC converter stage, the converter stage to be sued in the mobile information terminal of the invention should be embodied only after devices such as inductor, capacitor and diode are determined since the volume of the mobile information terminal is so small. Accordingly, in order to control the devices such as inductor, capacitor and diode whose dimensions are determined in harmony with properties of the liquid-filled lens, it is possible to generate different clocks shown in Fig. 5 and select and use clocks according to properties of the devices.

When the voltage generated in the converter module is higher than the curvature reference voltage (Vref) generated in the reference/bias voltage generator (440), the voltage conversion control module (424) considers it that a desired voltage is obtained and stops the voltage conversion.

The voltage division module (428) attenuates the voltage generated in the converter module (426) in a desired ratio and sends a divide voltage (div_hv) to be compared to the voltage comparison module.

The voltage comparison module (430) compares the curvature voltage (Vref) from the reference/bias voltage generator (440) with the divide voltage (div_hv) from the voltage division module. When the divide voltage (div_hv) is higher than the curvature reference voltage (Vref), the voltage comparison module (430) sends a control signal to the voltage conversion module so as to enable the voltage conversion control module (424) to stop a voltage conversion operation of the converter module (426).

The reference/bias voltage provision module (442) provides the curvature voltage generation module with a

constant voltage, and further other peripheral circuits with the bias voltage and reference voltage.

The curvature reference voltage generation module (444) is a digital to analog converter, which generates an analog voltage corresponding to the curvature value (drive voltage) of the liquid-filled lens transmitted from the image signal processor and outputs the curvature reference voltage (Vref) to the voltage comparison module.

The drive signal generator (460) outputs a drive signal to drive the liquid-filled lens, which finally outputs a drive signal to be provided to the liquid-filled lens.

The drive signal generator (460) includes a drive signal clock generation module 462, a low voltage differential signal generation module (464), and a high voltage differential signal generation module (466). The drive signal clock generation module (462) forms a period T of the differential signal shown in Fig. 2, which generates a frequency component, 1/T. The frequency generated at this time outputs the drive signal clocks from several hundreds of Hz to several tens of KHz so as to an optimum drive frequency according to object and electrostatic properties of the liquid-filled lens as described in the description for the voltage conversion clock generation module (422). The drive signal clocks are generated by the system clock inputted to the system clock generator (406) and signals controlled by the controller (404).

The low voltage differential signal generation module (464) outputs the differential signal as a low voltage of battery level of the mobile information terminal. The differential signal is output in a differential form to an RMS voltage applied between two electrodes of the liquid-filled lens.

That is, comparatively high RMS voltage can be obtained by driving the two terminals of the liquid-filled lens with differential signals (DRVP, DRVM), respectively, rather than making one of the two terminals of the liquid-

filled lens and grounded (GND) and applying the drive signal to the other terminal.

That is, since it is possible to obtain a higher RMS voltage by driving with the differential signals, compared with the case of using one differential signal by applying a minus drive signal (DRVM) to one of the two terminals of the lens and a plus drive signal (DRVP) to the other terminal, it is possible to output the high voltage drive signal to drive the lens even with the low voltage of the mobile information terminal.

The high voltage differential signal generation module (466) is a block to generate a real drive signal to drive the liquid-filled lens, which amplifies the low voltage differential signal (fdrv) output from the low voltage differential signal generation module (464) to a voltage level that is output from the DC to DC converter. Such a construction of the high voltage differential signal generation module (466) will be described in detail with reference to Fig. 9.

Fig. 6 is a circuit construction showing the converter module (426) shown in Fig. 4 in more detail.

The converter module (426) includes a DC-DC converter stage 610, a transient current detection stage (601), and a logic AND gate (602), where the DC-DC converter stage was described as the discontinuous DC-DC converter above.

The transient current detection stage (601) protects an inductor (604) and a first transistor (603) from transient current by limiting current flowing through the inductor and the first transistor and enhances the voltage conversion efficiency.

The first transistor means a general semiconductor switching device having functions to turn on/off current on a semiconductor such as MOSFET, BJT, JFET and BiCOMS Transistor. In the same manner, a second transistor (703) shown in Fig. 7 may also include all semiconductor devices which can perform switching function. Accordingly, it is

clear that the firs and second transistors (603) and (703) to be described below in embodying the invention include all semiconductor switching devices having functions to turn on/off current on the semiconductor such as MOSFET, BJT, JFET and BiCOMS Transistor. However, for simplicity of drawings, the first and second transistors (603) and (703) are shown as a symbol MOSFET in Figs. 6 and 7.

Meanwhile, since the transient current flowing through the inductor (604) and the first transistor (603) can deteriorate the inductor and the first transistor to decrease the voltage conversion efficiency or destroy the inductor and the first transistor in the worst case, a transient current detection stage (601) generates a transient current detection signal (ovc) to detect and cut off the transient current when it flows.

The transient current detection signal (ovc) is transferred to a logical AND gate (602). When the transient current detection signal is in the state "L", the logical AND gate (602) makes the drive clock (drv_clk) to drive the first transistor, "L" and maintains the first transistor in the OFF state. On the contrary, when the received transient current detection signal is in the state "H", the logical AND gate transmits the first transistor drive clock (drv_clk) as the same level as the voltage conversion real clock (rdc_clk), thereby operating the converter module normally.

A more detailed description of the transient current detection stage (601) is shown in Fig. 7.

In order to enhance the voltage conversion and generate a high voltage, a transient current is detected using a second transistor (703), an ideal current source (702) and a transient current detection voltage comparator (701). The method to detect the transient current is as follows.

First, the maximum current Imax flowing through the inductor (604) or the first transistor (603) is calculated

and the second transistor smaller than the first transistor by the first transistor/N (N is an integer) is selected. Further, it is controlled that the ideal current source (702) having a current capacity of Imax/N (N is an integer) is designed to flow the ideal current (Iref).

At this time, it is possible to reduce an error rate of the circuit manufacturing process when designing a semiconductor IC by designing the first (M1; 603) and second transistors (M2; 703) with same channel length and different channel widths, that is, the channel width of the second transistor being longer than that of the first transistor by N times, or designing N number of transistors with the same channel length and the same channel width.

As to resistance values obtained when the first and second transistors (603) and (703) designed as described above are turned on (referred to as ON resistance value), when an ON resistance value of the first transistor is R, the value of the second transistor is R*N (N is an integer). Accordingly, the voltage difference between the voltage (V1) of the first transistor generated when the maximum current Imax flows through the first transistor and the voltage (V2) of the second transistor generated when the reference current Iref flows through the second transistor maximum current Imax is 0[V] theoretically.

At this time, when the voltage V1 is higher than the voltage V2, the transient current flows through the inductor (604) and the first transistor (603), and the transient current detection voltage comparator (701) using the V1 and V2 as input signals changes the transient current detection signal (ovc) from "H(High)" to "L(Low)" as described in Fig. 8. Conversely, when the voltage V1 is lower than the voltage V2, since the current flowing through the inductor (604) and the first transistor (603) is not in the transient current state, the transient current detection signal (ovc) of the transient current detection voltage comparator (701) is continuously maintained in the state "H".

Meanwhile, when constructing the transient current detection circuit descried above, it is important that a reference constant current source is designed to set a current capacity variously so as to meet consumption current and driving voltage of different lenses, and such setting is performed by a transient current detection control signal (dc_cnt). Further, the transient current detection voltage comparator is controlled so that a comparison operation is necessarily performed during the first and second transistors are operated.

Fig. 8 is a view showing a timing diagram for each signal shown in Fig. 6.

A voltage conversion clock (dc_clk; 802) is a signal output from the voltage conversion clock generation module, and a control signal (ovv; 804) is an output signal of the voltage comparison module. Control signals (ovv), "H" and "L" are produced when the division voltage of the high voltage (hv) generated in the converter module (div_hv) is lower and higher than the reference voltage (Vref), respectively, whereby the control signals are output to the voltage conversion control module.

The control signal (ovv; 804) generates the voltage conversion real clock (rdc_clk; 806) through a voltage conversion control module. At this time, the voltage conversion real clock (rdc_clk) is continuously generated so as to perform the voltage conversion continuously when the voltage of the converter module (426) cannot reach to a desired voltage. When it reaches to the desired voltage, the clock is stopped and the DC converting is stopped.

Meanwhile, when an over current flows in the inductor (604) and the first transistor (603), the over current detection voltage comparator (701) detects it and outputs a transient current detection signal (ovc; 808) as "L". The logical AND gate (802) makes a logical AND of the transient current detection signal (ovc; 808) and the voltage conversion real clock rdc_clk, 806 and processes the

voltage conversion real clock (rdc_clk; 806) as "L" in a section where the transient current detection signal is in a state "L", thereby generating the first transistor driving clock. Therefore, the logical AND gate (802) turns off the first transistor to prevent it from being damaged due to the transient current.

Fig. 9 is a view showing a detailed circuit construction of the high voltage differential signal generation module shown in Fig. 4, where the high voltage differential signal generation module is a real drive module to drive the liquid-filled lens.

The voltage level converter (901) converts the voltage of the low voltage drive signal (fdrv) generated in the low voltage differential signal generation module from a battery voltage level of the mobile information terminal into the high voltage (hv) level input from the converter module.

The first drive buffer (902) and the second drive buffer (903) are designed to be buffers whose capacities are larger than those of buffers needed to drive the liquid-filled lens so as to become as close as possible to the ideal buffer.

While the volume of current and driving faculty to drive the lens are controlled using first and second resistors (904 and 905), the first and second resistors are used to control a slope which is used to maintain the rising time (Tr) and falling time (Tf) constant in the differential signal shown in Fig. 2 regardless of amplitudes of signals used to drive the liquid-filled lens.

The plus drive signal (DRVP) and the minus drive signal (DRVM) which are generated through the first drive buffer and first resistor and the second drive buffer and second resistor (902, 903, 904 and 905), can generate signals as shown in Fig. 2 with the same shape and reverse phase in spite of errors of semiconductor manufacturing process for drive buffers and resistors and changes of high

voltages (hv).

Accordingly, the liquid-filled lens drive signals generated from the processes described above generate comparatively small electromagnetic interference noises and can drive the liquid-filled lens efficiently with a less current.

While the invention has been shown and described with reference to certain exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

[Effects]

According to the invention, a liquid-filled lens driver circuit can be mounted in a mobile information terminal as a one-chip with ease by generating a voltage level to drive the liquid-filled lens from a low voltage such as a battery voltage of a mobile information terminal. Further, efficiency of the voltage provided can be enhanced by applying the drive signal of the liquid-filled lens in a differential form and then generating comparatively high RMS drive voltage.

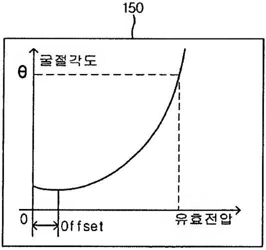
[Abstract]

The present invention relates to a liquid-filled lens driver circuit for generating a liquid-filled lens drive signal and its integrated circuit, capable of generating a high voltage drive signal from a low voltage source and then a differential type drive signal so as to enhance an efficiency of a low voltage source. The liqid-filled lens driver circuit of the invention includes a liquid-filled lens driver circuit for receiving a lens driver control signal (CTL) from an image signal processor (ISP) and driving a liquid-filled lens, including an input/output interface for exchanging the lens driver control signal and a state information data of the liquid-filled lens with an image signal processor according to a desired signal transmission protocol; a system clock generator for generating a system clock; a high voltage generator for generating a high voltage to drive the liquid-filled lens from a low voltage of a battery in a mobile information terminal; a reference/bias voltage generator for providing a reference voltage and a bias voltage to operate the liquid-filled lens driver circuit; a driver signal generator for generating a desired output waveform to drive the liquid-filled lens and then generating the final driving signal of the liquid-filled lens by increasing the output waveform to a high voltage level generated in the high voltage generator; and a controller for controlling each functional unit to drive the liquid-filled lens.

[Drawings]

Fig. 1a
Refraction angle

Fig. 1b



Refraction angle

Efficient voltage

Fig. 2
DRV Voltage

Fig. 3
300: Image signal processor
400: Lens driver circuit
320: Lens set
340: Image sensor

Fig. 4
402: Input/output interface
404: Controller
406: System clock generator
422: Voltage conversion clock generation module
424: Voltage conversion control module
426: Converter module
442: Reference/bias voltage provision module
444: Curvature reference voltage generation module
428: Voltage division module
430: Voltage comparison module
462: Drive signal clock generation module
464: Low voltage differential signal generation module
466: High voltage differential signal generation module

Fig. 6
422: Voltage conversion clock generation module
424: Voltage conversion control module
428: Voltage division module
601: Transient current detector
602: Logical AND gate

Fig. 9
901: Voltage level converter